Marine Physical Laboratory

Ocean Optics, Ocean Imaging and Optical Tomography

Jules S. Jaffe

Final Report to the
Office of Naval Research
Contract N00014-89-J-1419
For the Period 10-01-88 - 9-30-93

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University of California, San Diego
Marine Physical Laboratory
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Abstract

The broad goal of this research is to address the problem of understanding the propagation of light in the ocean and its ramifications for underwater imaging In particular, we are interested in developing inversion algorithms for determining the total absorbtion and scattering coefficients and the small angle values of the volume scattering function from simple optical experiments such as the propagation of collimated light beams over distances of several total attenuation lengths. This is particularly important in understanding the limitations of current computer models which predict the propagation of light underwater. Our current work has concerned the forward modeling problem via the development of a Monte Carlo model. We plan to extend these studies to include inversion techniques based on the same model. We also plan to address the question of designing and experimenting with in-situ remote 3-dimensional sensing systems. These systems present the opportunity to allow measurement of the variability of ocean optical parameters within a given volume. Some simple experiments are proposed to demonstrate the feasibility of these methods to measure in-situ fluorescence in 3-dimensional volumes.

Project Objectives

The near term objectives of this program are to evaluate the correctness of the approximations that are used in our current underwater modeling system. This model includes only single scattering events and a linearization of the image formation process. We are also exploring new techniques which can be used for measuring the inherent optical quantities in volumes.

Project Results

1) 3-dimensional Underwater Imaging

An underwater optical serial sectioning technique has been developed to measure in-situ three dimensional distributions of biological particles. The technique involves scanning a thin plane of laser light through a range of distances parallel to the imaging plane of a digital CCD camera. Images of induced fluorescence in the sequentially illuminated planes are recorded. An inverse method is then used to reconstruct three dimensional chlorophyll and distributions from the plane images. Computer simulations of the image formation and reconstruction process indicate that the underwater optical serial sectioning technique is practical for in-situ determination and analysis of chlorophyll and microstructures for concentrations as low as 0.1 mg Chl a / meter cubed in 1 meter cubed water volumes.

2) Monte Carlo Modeling of Point Spread Functions

A Monte Carlo model has been used to determine a set of point spread functions and modulation transfer functions for underwater imaging in different environments. The results have been used to examine the validity of a linear approximation theory. The conclusions are that the linear approximation theory works to some extent, however, a slight modification can be used in order to obtain good quantitative agreement. In particular, an empirical effective beam attenuation function is used for each different environment in order to insure the accuracy of the linear treatment. In addition, the ramifications of Well's small angle scattering theory that predicts the Point Spread Function (PSF) from a knowledge of the Volume Scattering Function (VSF) is examined. Discrepancies are noted between a predicted and computationally obtained Modulation Transfer Function (MTF).

Publications:

1. Palowitch, Andrew W. and Jaffe, J.S., "Experimental Determination and Modeling of Volumetric Optical Properties," Proc. Ocean Optics XI, SPIE 1992 International Symposium on Optical Applied Science and Engineering, Vol. 1750 (July 19-24, 1992)
2. Jaffe, Jules S., "Valididty and Range of Linear Approximations in Underwater Imaging," Proc. Ocean Optics XI, SPIE 1992 International Symposium on Optical Applied Science and Engineering, Vol. 1750 (July 19-24, 1992).
3. Jaffe, Jules S., "Robotic Sensors: Acoustic and Optical Options," Proc. Acoustic Signal Processing for Ocean Exploration, NATO Advanced Study Institute 1992, Madeira, Portugal (July 26-August 7, 1992)
4. Jaffe, Jules S., "Three-dimensional Imaging Overview", In "Three-dimensional Animal Aggregations: Mechanisms and Functions", J.K. Parrish, W. M. Hamner and C.T. Prewitt (editors.) In Press- U. C. Press, to appear, 1993.
5. J. Jaffe, "Monte Carlo modeling of underwater image formation: validity of linear and small angle approximations," Applied Optics (accepted subject to revision).
6. Palowitch, A. W. and Jaffe, J.S., "Determination of three dimensional ocean chlorophyll distribution from underwater serial sectioned fluorescence images" (accepted for publication, Applied Optics).

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Office of Naval Research (3)
Department of the Navy
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660
Atten: Steve Ackleson
Code 3230P

Administrative Grants Officer (1)
Office of Naval Research
Resident Representative
University of California, San Diego, 0234
8603 La Jolla Shores Drive
San Diego, CA 92093-0234

Commanding Officer (1)
Naval Research Laboratory
Atten: Code 2627
Washington, D.C. 20375-5320

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